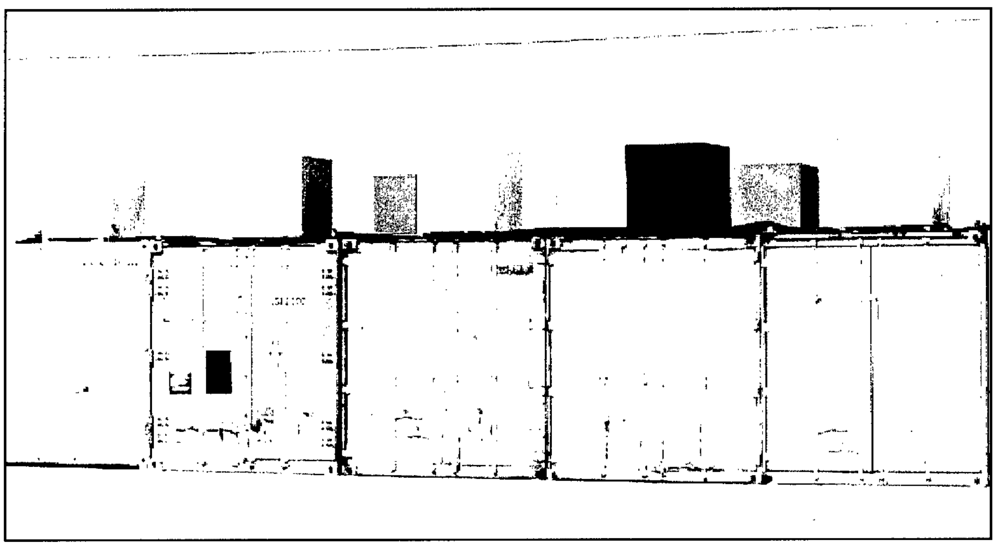
NAVAL FACILITIES ENGINEERING SERVICE CENTER
Port Hueneme, California 93043-4370

TECHNICAL MEMORANDUM
TM-2330-SHR

PRELIMINARY INVESTIGATION INTO THE EXTERIOR USE OF ELASTOMERIC ACRYLIC COATINGS FOR NAVAL FACILITIES



by

Joseph H. Brandon
C. Dave Gaughen

March 2000

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13. ABSTRACT *(Maximum 200 words)*

This effort is in response to a request by the Naval Facilities Engineering Command (Atlantic Division) to conduct a preliminary investigation into elastomeric acrylic coatings for exterior use by Naval facilities. Findings are as follows: (a) A water-based, direct-to-metal (DTM) acrylic primer followed by 20 mils dry of a water-based, elastomeric acrylic provided excellent protection to steel for over 2.75 years in a coastal marine environment, (b) elastomeric acrylics developed sound adhesion to 17 combined coated and uncoated substrates, (c) elastomeric acrylics generated low levels of residual cure stress (RCS) and, when used in maintenance painting, should transfer negligible stress to existing coatings, (d) elastomeric acrylics applied directly to steel resulted in significant flash rusting, however, the flash rusting neither affects adhesion nor bleeds into a topcoat when overcoated, (e) elastomeric acrylics exhibited acceptable performance when subjected to 1 week immersion in tap water and 3 weeks exposure in 95% relative humidity, (f) elastomeric acrylics displayed high performance when applied to Naval and commercial roofs, and (g) elastomeric acrylics may be suitable for use on a variety of exterior substrates located in diverse environments.

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EXECUTIVE SUMMARY

This effort is in response to a request by the Naval Facilities Engineering Command (Atlantic Division) to conduct a preliminary investigation into Elastomeric Acrylic coatings for exterior use by Naval Facilities.

FINDINGS

- A water-based, Direct to Metal (DTM) acrylic primer followed by 20 mils dry of a water-based, Elastomeric Acrylic has provided excellent protection to steel for over 2.75 years in a coastal marine environment
- Elastomeric Acrylics developed sound adhesion to seventeen combined coated and uncoated substrates
- Elastomeric Acrylics generate low levels of Residual Cure Stress (RCS) and, when used in maintenance painting, should transfer negligible stress to existing coatings
- Elastomeric Acrylics applied direct to steel resulted in significant flash rusting: however, the flash rusting neither affects adhesion nor bleeds into a topcoat when overcoated
- Elastomeric Acrylics exhibit acceptable performance when subjected to one-week immersion in tap water and three-weeks exposure in 95 % Relative Humidity
- Elastomeric Acrylics have displayed high performance when applied to Naval and Commercial roofs
- Elastomeric Acrylics may be suitable for use on a variety of exterior substrates located in diverse environments

RECOMMENDATIONS

1) Initiate laboratory testing for accelerated weathering.
2) Initiate testing at the Naval Research Laboratory (NRL) exposure site in Florida.
3) Identify Naval structures for Elastomeric Acrylic demonstration.
4) Validate Elastomeric Acrylic performance.

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INTRODUCTION

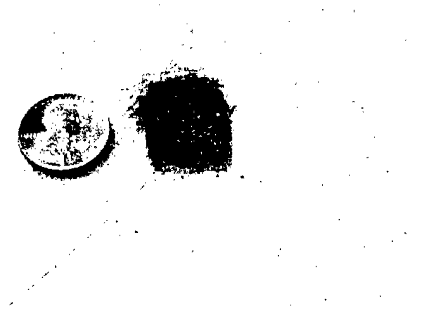
This effort is in response to a request by the Naval Facilities Engineering Command (Atlantic Division) to conduct a preliminary investigation into Elastomeric Acrylic coatings for exterior use by Naval Facilities. Elastomeric Acrylics, traditionally used in the roofing industry, may provide a viable and environmentally acceptable solution when used in the exterior painting of industrial and architectural Naval structures.

BACKGROUND

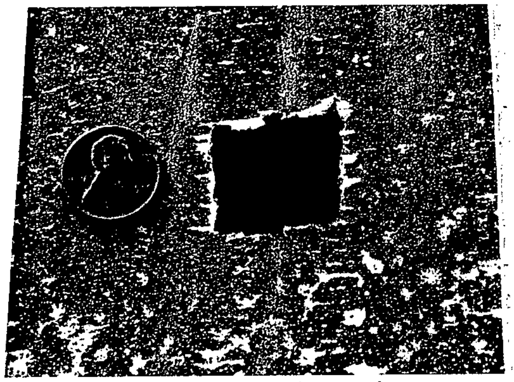
In 1997, the Navy conducted an investigation into the thermal properties associated with various colors of Elastomeric Acrylic roof coatings (see cover photo)[1]. Elastomeric Acrylics were applied at approximately 20 mils dry (1 mil = 0.001") over grit blasted steel primed with a water-based, Direct to Metal (DTM) acrylic primer. The demonstration site was located in Southern California (Port Hueneme) and at a distance of one-mile from the harbor. At 2.75 years exposure, the boxes displayed performance equal to the ratings assigned at the end of the one-year project: A) Chalking, "None" (ASTM-D-4214[2]: Method B), B) Mildew Resistance, "10" (ASTM-D-3724), C) Horizontal Surface Dirt Pickup, "10-" (ASTM-D-3724), D) Vertical Surface Dirt Pickup, "10" (ASTM-D-3724), E) Horizontal Surface Rust Grade, "7^+ to 9^{+}" (ASTM-D-610), and F) Vertical Surface Rust Grade, "9^+ to 10" (ASTM-D-610). At one-year exposure and on two horizontal surfaces, one-inch coating squares were removed to unveil the original white-metal blast. At 2.75 years exposure, the coating system surrounding the original squares was removed to revealed the same uncorroded, white-metal. Although Elastomeric Acrylic exposure has been relatively short, it is still however, noteworthy.

Poorest performing horizontal area @ 2.75 years exposure.

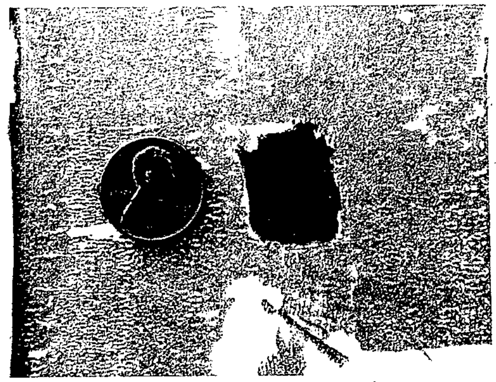
Horizontal surface @ 2.75 years. Rusted Square "A" exposed for 1.75 years.



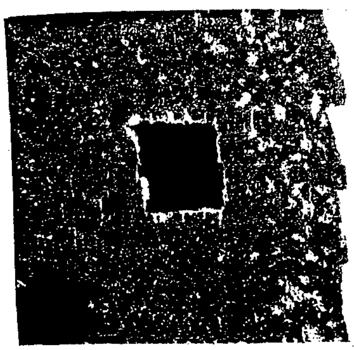
Horizontal surface @ 2.75 years. Rusted Square "B" exposed for 1.75 years.



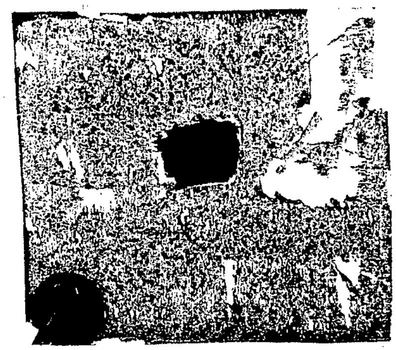
Coating removed: no undercutting at Square “A”, original white metal (tan spots are primer).



Coating removed: no undercutting at Square “B”, original white metal (tan spots are primer).



One-day following coating removal: coastal marine environment, Square “A”.



One-day following coating removal: coastal marine environment, Square “B”.

ELASTOMERIC ACRYLIC PROPERTIES

Typical Elastomeric Acrylic properties are presented in Tables 1, 2, whereas minimum performance requirements for Elastomeric Acrylic roof coatings are listed in Table 3.

Table 1: Typical Elastomeric Acrylic Properties[3]

PROPERTY	*VALUE OR RESULT*
Solids by Volume	57 – 60
Volatile Organic Compounds (VOC) Direct to Metal (DTM) Primer Elastomeric Acrylics	 180 g/l ≤ 50 g/l
Tensile Strength (ASTM-D-412)	258 psi – 646 psi
Percent Elongation (ASTM-D-412)	235 % - 446 %
Shore A Hardness (ASTM-D-2240)	62 – 77
Flexibility: 1/8” Mandrel Bend @ –15°F	Pass
Application Temperature Range	50°F – 90°F
Vertical Application	≤ 8 mils DFT
Horizontal Application	≤ 15 mils DFT
Recoat Time	2 – 8 hours
Percent White Reflectivity (ASTM-E-1347)	> 90

Table 2: Additional Elastomeric Acrylic Properties[4]

Water Immersion Weight Increase @ 168 hrs	Coefficient of Thermal Expansion: 0°F – 140°F	Modulus of Elasticity @ 80°F	Taber Abrasion: 1000 cycles, 1 kg weight, CS-17 wheel	Glass Transition Temperature T(g)
12.4 %	102 µin/in°F	72,500 psi	39.1 mg wt. Loss	-18°F

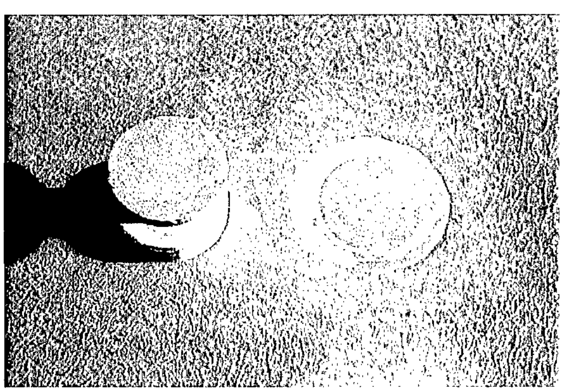
Table 3: Minimum Elastomeric Acrylic Requirements for Roofs (ASTM-D-6083)[5]

PROPERTY	*VALUE OR RESULT*
Volume Solids (ASTM-D-2697)	≥ 50 %
Percent Elongation (ASTM-D-2370)	≥ 100 %
Tensile Strength (ASTM-D-2370)	≥ 200 psi
Percent Elongation @ 1000 hrs accelerated weathering	≥ 100 %
Permeance (ASTM-D-1653)	≤ 50 perm
Water Swelling (ASTM-D-471)	≤ 20 % weight increase
Accelerated Weathering @ 1000 hrs (ASTM-D-4798)	No cracking or checking
Wet Adhesion (ASTM-C-794 or D-903)	≤ 2.0 pli
Fungi Resistance @ 28 days (ASTM-G-21)	Zero rating
Tear Resistance (ASTM-D-624)	> 60 lbf/in
Flexibility @ -15°F, 14 mils DFT, 1/2" mandrel bend, 1000 hrs accelerated weathering	Pass

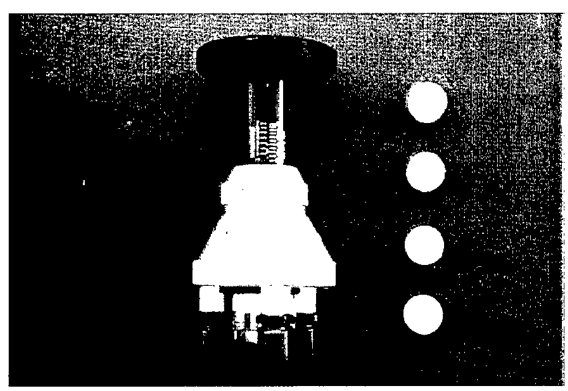
EXPERIMENTAL

Elastomeric Acrylics were evaluated for the following: A) Adhesion to various substrates, B) Residual Cure Stress (RCS), C) Qualitative peel strength, D) Effects of flash rusting, and E) 95 % Relative Humidity exposure. The Elastomeric Acrylics were applied either by roller or brush and, prior to testing, cured for a minimum of 168 hours. Commercial formulations with properties as listed in the above Tables 1, 2 were evaluated.

Adhesion to Various Substrates



Elastomeric Acrylic cohesive failure over epoxy polyamide: cohesive failure represents maximum adhesion to epoxy polyamide.



Elcometer™ adhesion tester and 3/4" pull-off coupons.

Elastomeric Acrylics were applied to the following substrates and evaluated for pull-off strength (ASTM-D-4541): A) Weathered aliphatic urethane, B) Grit blasted aluminum, C) Alkyd primer, D) Weathered alkyd, E) Asphaltic concrete, F) Concrete, G) Concrete Masonry Unit, H) Weathered Elastomeric Acrylic, I) Epoxy polyamine, J) Epoxy polyamide, K) Galvanized steel, L) Moisture cured urethane, M) Polysulfide joint sealant, N) Polyurethane foam, O) Plywood, P) Grit blasted steel, and Q) Stucco. Table 4 lists Elastomeric Acrylic pull-off strengths when applied to the above substrates.

Table 4: Elastomeric Acrylic Pull-Off Strengths

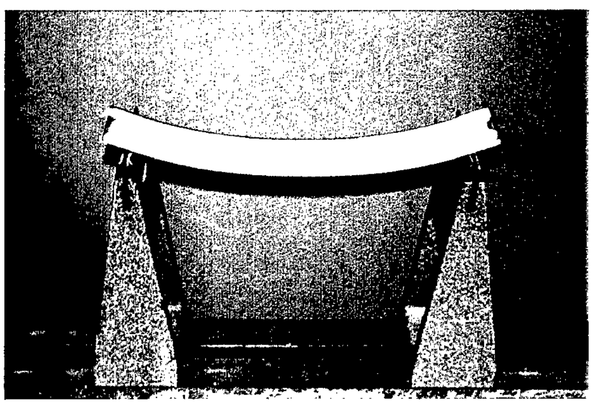
SUBSTRATE	*PULL-OFF STRENGTH (psi)**
Aliphatic Urethane: 2.5 year old system	
Elastomeric Overcoat/Unsanded, non-washed Urethane (dirt wiped off dry)	290 psi (ECF[a])
Aluminum	
Elastomeric/Grit Blasted	450 psi (ECF)
Elastomeric/168 hrs immersion, tap water (wet adhesion)	105 psi (EAF[b])
Elastomeric/168 hrs immersion, tap water, 24 hours drying	270 psi (ECF)
Alkyd Primer	150 psi (MCF[c])
Elastomeric/Alkyd	150 psi (MCF)
Alkyd System to Aluminum (weathered)	73 psi (MAF[d])
Elastomeric/Alkyd (washed)	73 psi (MAF)
Asphaltic Concrete (AC)	248 psi @ 63°F; 106 psi @ 108°F (MCF)
Elastomeric/Washed AC	125 psi @ 90°F (MCF)
Concrete	≥ 250 psi (MCF)
Elastomeric/Weathered concrete, washed	85 psi (EAF)
Elastomeric/Weathered concrete, disk ground	125 psi (EAF)
Elastomeric/Concrete sample, grit blasted	190 psi (EAF)
Concrete Masonry Unit (CMU)	285 psi (MCF)
Elastomeric/Washed CMU	93 psi (EAF)
Elastomeric Acrylic: 2.5 year-old system	455 psi (ECF)
Elastomeric Overcoat @ 6 hrs cure	290 psi (ECF)
Epoxy Polyamine (unweathered)	
Elastomeric/Epoxy polyamine	215 psi (EAF)
Epoxy Polyamide (unweathered)	
Elastomeric/Epoxy polyamide	263 psi (ECF)
Galvanized Steel	
Elastomeric/Galvanized steel	310 psi (ECF)
Moisture Cured Urethane (MCU), Zinc-Rich	
Elastomeric/MCU, unweathered	200 psi (EAF)
Elastomeric/MCU, unweathered, sanded	295 psi (ECF)
Elastomeric/MCU, weathered	313 psi (ECF)
Polyurethane Foam (PUF)	90 psi (MCF)
Elastomeric/PUF	90 psi (MCF)
Polysulfide Airfield Joint Sealant	90 psi (MCF)**
Elastomeric/Polysulfide	≥ 90 psi (MCF)
Plywood	193 psi (MCF)

Elastomeric/Plywood (unweathered)	193 psi (MCF)
Steel, Grit Blasted	
Elastomeric/DTM Acrylic primer	408 psi (ECF)
Stucco	82 psi (MCF)
Elastomeric/Stucco	82 psi (MCF)

*Values represent the average from a minimum of three pull-off tests. [a]ECF = Elastomeric Cohesive Failure. [b]EAF = Elastomeric Adhesive Failure. [c]MCF = Material Cohesive Failure. [d]MAF = Material Adhesive Failure. **Manufacturer's reported value.

Pull-off strengths with an adjacent ECF (Elastomeric Cohesive Failure), MCF (Material Cohesive Failure), and MAF (Material Adhesive Failure) represent maximum Elastomeric Acrylic adhesion whereas pull-off strengths with an adjacent EAF (Elastomeric Adhesive Failure) may indicate low adhesion. When applied to stucco, for example, the Elastomeric Acrylic developed an adhesive strength exceeding the stucco's cohesive strength and pull-off testing resulted in the removal of stucco chunks (Material Cohesive Failure: MCF). Conversely, when the Elastomeric Acrylic was applied to concrete, the coating somewhat failed to bite into the concrete and pull-off testing resulted in Elastomeric Adhesive Failures (EAF). Furthermore, each Elastomeric Cohesive Failure (ECF) indicates high chemical/mechanical substrate adhesion and suggests acceptable peel strength.

Residual Cure Stress


Shim bending technique.

Residual Cure Stress (RCS) was quantified using the freely supported beam method (shim bending technique)[6,7,8,9]. The Elastomeric Acrylic was applied to three stainless steel shims (0.012" x 10" x 2": SS 302) at approximately 38 mils dry. The initial shim deflection, prior to coating, was used as the zero point. Equations (1) and (2) are presented in Reference 8 and were used to calculate RCS.

$$S_1 = E_s t^3/[6c_1(t + c_1)(1 - v_s)R] + E_1(t + c_1)/[2R(1 - v_1)] \qquad (1)$$

$$R = L^2/8d \qquad (2)$$

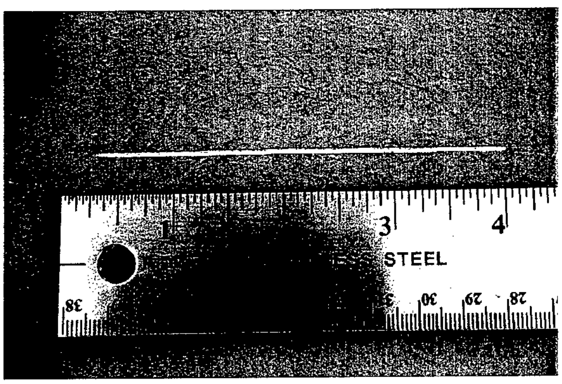
where

S_1 = Residual Cure Stress (RCS)
E_s = modulus of elasticity for substrate (28,000,000 psi[10])

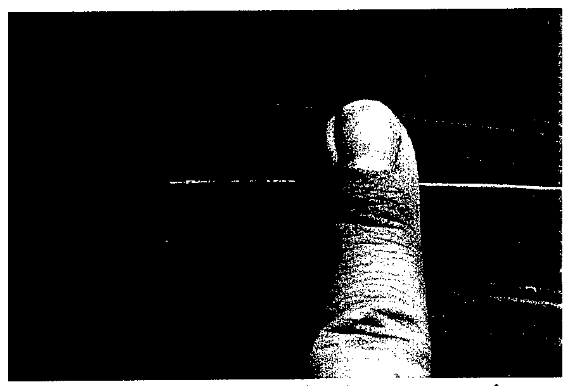
E_1 = modulus of elasticity for single coating layer (E value @ 73°F was used)
v_s = Poisson's ratio for substrate (0.283[11])
v_1 = Poisson's ratio for coating layer[12]
t = substrate thickness (0.012")
c_1 = average thickness of coating layer (DFT)
R = curvature radius of the coated, bent substrate
L = length between knife-edge shim supports (8.5")
d = vertical deflection following cure

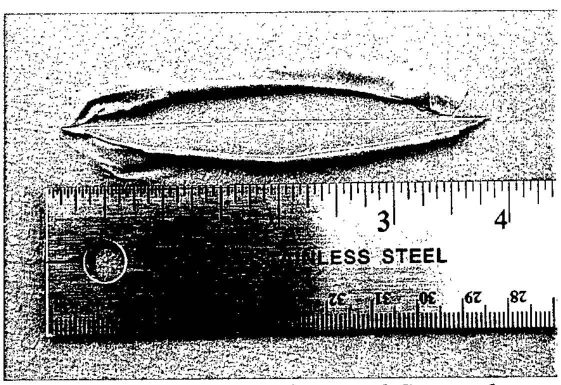
A Residual Cure Stress (RCS) of 1.5 psi per mil or 57 psi at 38 mils was transferred to the shim during the Elastomeric Acrylic's cure and represents a coating with extremely low RCS. The tested Elastomeric Acrylic is an excellent candidate for use in overcoating sound but weathered coatings and, when used, should transfer only a negligible quantity of stress to the existing coating.

Qualitative Peel Strength (QPS)

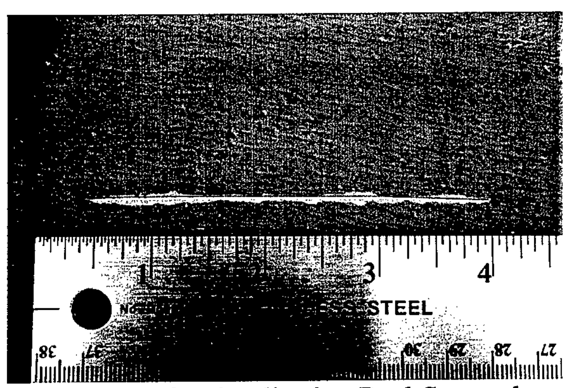


Initial scribe cut.


Rub scribe cut perpendicular to cut using moderate finger pressure.



Failed test for Qualitative Peel Strength: Elastomeric Acrylic topcoat was peeled away from the gray urethane primer.



Passing test for Qualitative Peel Strength: Elastomeric Acrylic topcoat was not peeled away from the yellow alkyd primer.

Elastomeric Acrylics display a high percent elongation and a moderate tensile strength. If either substrate or intercoat adhesion is below the Elastomeric Acrylic's tensile strength and if the coating is subjected to high levels of stress, the Elastomeric Acrylic

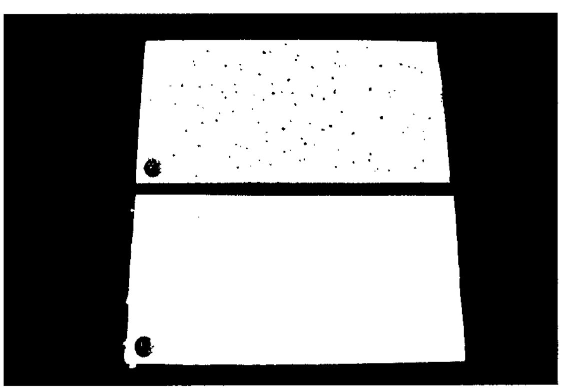
may lift and fail in monolithic sheets[13]. As such, Elastomeric Acrylics must display high peel strength adhesion in addition to acceptable pull-off strength adhesion. The test for Qualitative Peel Strength (QPS) is experimental and was used to identify Elastomeric Acrylics displaying low peel strength adhesion. The experimental procedure for QPS testing is as follows: *A 1" to 3" length, 1/32" width, V-shaped score was placed in a straight line and completely through the Elastomeric Acrylic. The score was rubbed, using moderate finger pressure, ≥ 8 complete passes back and forth across the score (perpendicular to the score) in an attempt to peel (roll) the coating away from the score. The Elastomeric Acrylic displayed sound adhesion if, after rubbing per scored area, ≤ 1/8" of coating was peeled away from the score (total width of coating removed perpendicular to the score is ≤ 5/32": 1/8" + 1/32").* Results from QPS testing are presented in Table 5.

Table 5: Qualitative Peel Strength (QPS) Test Results

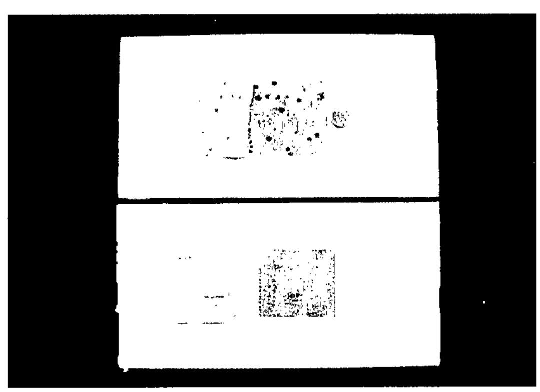
SUBSTRATE	*QPS TEST RESULT*
Aluminum: grit blasted	
Elastomeric/168 hrs immersion in tap water	Pass
Alkyd Primer	
Elastomeric/Alkyd	Pass
Moisture Cured Urethane (MCU), Zinc-Rich Primer	
Elastomeric/MCU	Fail
Elastomeric/MCU, sanded with 120 grit sandpaper	Pass
Epoxy Polyamide Primer	
Elastomeric/Epoxy, 3-weeks, 95 % R/H	Pass

Elastomeric Acrylics with passing QPS are sound and indicate surface preparation was adequate. However, Elastomeric Acrylics failing QPS testing require either additional surface preparation (such as sanding) or may be incompatible with the substrate.

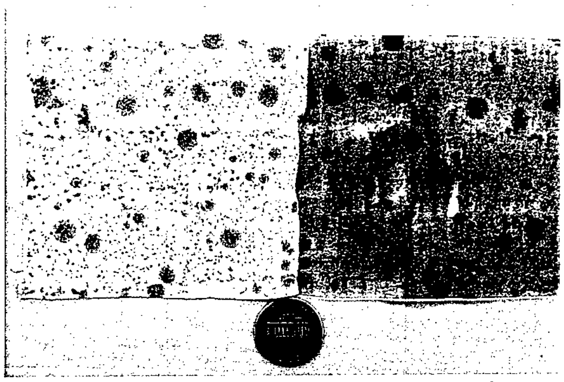
Effects of Flash Rusting



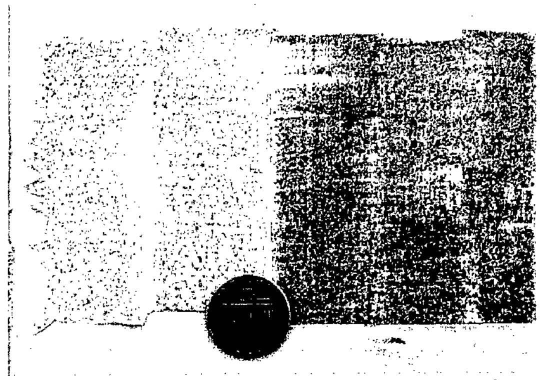
Various degrees of flash rusting: white Elastomeric Acrylic applied direct to blasted steel.



Gray Elastomeric Acrylic topcoat covered the flash rusting in one coat.



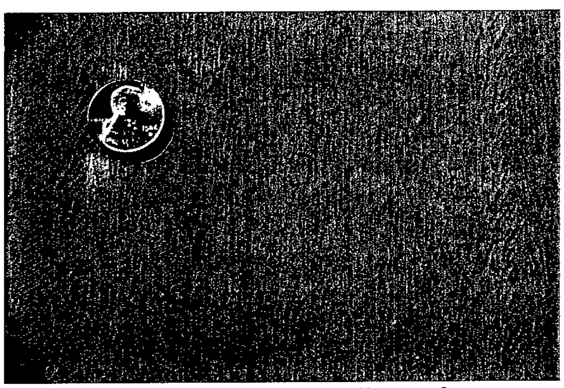
Close-up of flash rusting at Elastomeric Acrylic/steel interface.



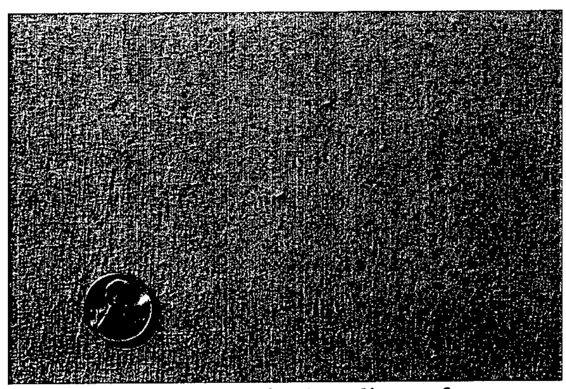
Close-up of flash rusting at Elastomeric Acrylic/steel interface.

Adhesion testing was performed on the gray topcoat and glue failures occurred at an average value ≥ 360 psi (ASTM-D-4541: 3 tests). Preliminary results suggest acrylic flash rusting does not interfere with either substrate or intercoat dry adhesion. However, an extended overcoat window may be required in order to prevent the transfer of rust bleed into subsequent coats.

95 % Relative Humidity (R/H) Exposure



Resulting Elastomeric Acrylic surface over epoxy polyamine: 3-weeks, 95 % R/H (coarse texture is from roller application)



Resulting Elastomeric Acrylic surface over epoxy polyamide: 3-weeks, 95 % R/H (coarse texture is from roller application).

Two Elastomeric Acrylic samples were placed in a concrete curing room for a period of 3-weeks: A) Elastomeric Acrylic applied in one coat to an epoxy polyamide primer, and B) Elastomeric Acrylic applied in one coat to an epoxy polyamine primer. The concrete curing room is maintained at an approximate Relative Humidity of 95 % and water spray saturates the room several times each hour. Immediately following exposure, the samples were visually examined and displayed 0 % coating anomalies including biological growth. Adhesion testing was performed 24 hours following exposure and values are presented in Table 6. Results from short-term, high humidity exposure suggest the Elastomeric Acrylic may be a viable topcoat for epoxy polyamide primers such as military specification Mil-DTL-24441.

Table 6: Elastomeric Acrylic Adhesion following 3-weeks, 95 % R/H Exposure

SUBSTRATE	*PULL-OFF STRENGTH (psi)**
Initial: Elastomeric/Epoxy Polyamine	215 psi**
Exposed: Elastomeric/Epoxy polyamine	≥ 265 psi***
Initial: Elastomeric/Epoxy Polyamide	263 psi**
Exposed: Elastomeric/Epoxy polyamide	≥ 290 psi***

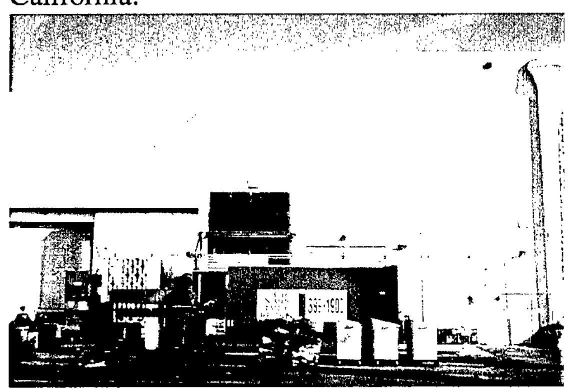
*ASTM-D-4541: Values represent the average of three adhesion tests. **Initial testing was performed in direct sunlight @ approximately 80°F. ***Exposed testing was performed @ approximately 63°F.

NAVY AND COMMERCIAL USE

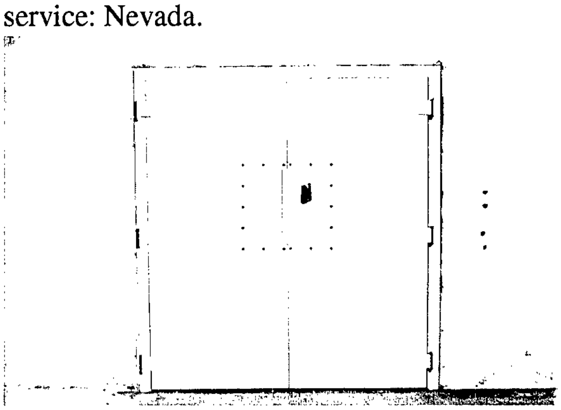
Elastomeric Acrylic > 5 years exterior service: Nevada.

> 900,000 ft^2 of Elastomeric Acrylic roof coating (85 buildings): > 2 years service, California.

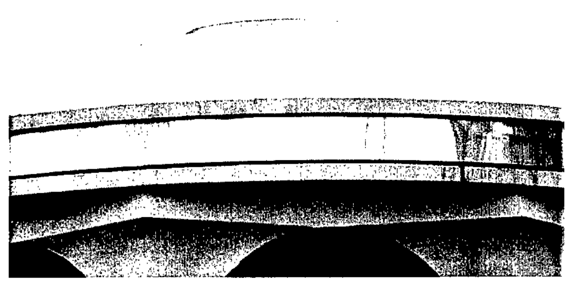
Elastomeric Acrylic > 5 years exterior service: Nevada.



Elastomeric Acrylic ≥ 4 years exterior service: Nevada.



Elastomeric Acrylic ≥ 1 year exterior service: California (NFESC Demo).



Elastomeric Acrylic > 8 years exterior service: Nevada.

Elastomeric Acrylics have traditionally been used in the roofing industry and with a history of high commercial performance: A) Washoe Progressive Care Center (56,000 ft^2: Reno, NV), B) Santa Anita Park (900,000 ft^2: Arcadia, CA), C) Hannibal Industries, Inc. (46,000 ft^2: Los Angeles, CA), D) Antioch School District (450,000 ft^2: Antioch, CA), and E) Porsche of America (80,000 ft^2: Reno, NV)[14]. The Navy began recommending Elastomeric Acrylic roof coatings in 1979 and, at present, Elastomeric Acrylics are specified in NFGS-07572C titled "Coatings for Foamed Roofing[15]."

DISCUSSION

PERFORMANCE REQUIREMENTS

Adhesion

Elastomeric Acrylic formulations are required to develop sound adhesion, under both wet and dry conditions, when applied to primers, existing coatings, and to various substrates. When tested for adhesion, sound Elastomeric Acrylic adhesion is displayed when the following test results are produced: 1) Qualitative Peel Strength (QPS): Dry, Pass; ≥ 24 hours Wet, Pass, and 2) Pull-off strength (ASTM-D-4541): Dry, either substrate failure, Elastomeric Acrylic cohesive failure, or Elastomeric Acrylic adhesive failures ≥ 275 psi; ≥ 24 hours wet, ≥ 95 psi.

Alkali and Acid Resistance

If the Elastomeric Acrylic is to be applied direct to concrete, CMU, mortar joints, galvanized steel, and stucco, resistance to continuous exposure from moderately high alkali is required (pH ≥ 9.6). Alkali sources and pH values per substrate are presented in the below section titled Substrates. In environments with high levels of pollution, the Elastomeric Acrylic is required to resist, with minimal degradation, cyclical exposure to acidic rain, fog, and dew (pH > 4.0). If the Elastomeric Acrylic contains high levels of calcium carbonate (extender pigment) and is subjected to acidic environments, the coating may develop surface frosting[16]. When calcium carbonate reacts with environmental acids and water, an undesirable film of white bicarbonate may form on the coating's surface (frosting)[17].

Biological Growth Resistance

In either tropical climates or locations with intermittent high levels of humidity, the Elastomeric Acrylic is required to display extended resistance to biological growth (≥ 10 years). Under the right conditions, mold, yeast, algae, and bacteria may attach to a coating and use it as a source of nutrition[18]. Traditionally, zinc oxide in combination with commercially available biocides synergistically combats biological growth[19].

Corrosion Mitigation

When applied to steel, the Elastomeric Acrylic is required to assist the primer by acting as a barrier coating. An effective barrier coating displays low permeability to moisture, chloride salts, oxygen, and remains soundly adhered to primers when wet.

Dirt Pickup Resistance

In order to be aesthetically competitive as either an architectural or industrial coating, the Elastomeric Acrylic is required to display high resistance to dirt pickup. Past research has shown that coatings with a low Glass Transition Temperature ($T_{(g)}$), such as the Elastomeric Acrylic, may display poor resistance to dirt pickup[20]. However, Elastomeric Acrylic resins have recently been designed with increased resistance to dirt pickup[21].

Pigment Retention

Elastomeric Acrylic pigment retention is extremely important when coating either large antenna towers or architectural structures. If, for example, a coating with low pigment retention is used to mark a large antenna tower, pigment bleed may discolor the alternating red/white markings and decrease the tower's visibility. Furthermore, an architectural structure with visual pigment bleed decreases overall building aesthetics and is never desired. Therefore, the Elastomeric Acrylic is required to be formulated with pigments that display negligible pigment bleed as the coating weathers.

Sub-Freezing Exposure

In climates with sub-freezing temperatures, the Elastomeric Acrylic is required to remain flexible and resist cracking, checking, and lifting when applied to various substrates.

UV Resistance

The Elastomeric Acrylic is required to remain stable and largely unaffected when subjected to years of UV exposure. This is generally accomplished through a combination of reflective pigments, pigments with selective absorption, UV light absorbers, light stabilizers, anti-oxidants, and minimizing the use of plasticizers[22].

Water Resistance

The Elastomeric Acrylic is required to retain its' physical properties when exposed to prolonged water contact and, when subjected to wind driven rain, prevent water intrusion. The Elastomeric Acrylic is also required to display sufficient hydrophobicity (repels water) and minimal water absorption which reduces the ingress of moisture to substrates.

SUBSTRATES

Aluminum

The Coefficient of Thermal Expansion (CTE) for aluminum is 13.0 x 10^{-6}in/in°F[23]. When aluminum corrodes, aluminum oxide and aluminum hydroxide corrosion products are generated which display a $pH > 7$[24]. The Elastomeric Acrylic exhibited high adhesion to aluminum and contains flexibility sufficient to compliment aluminum's high CTE. If applied direct to properly prepared aluminum, the Elastomeric Acrylic should display high performance.

Concrete, Concrete Masonry Units (CMU), Stucco, and Brick

The CTE for a cementitious material is from 3.0 – 10.0 x 10^{-6}in/in°F[25]. Cementitious materials formulated with lime (calcium oxide) generally display an initial pH > 12.5[26]. As time progresses (≥ 28 days), the initially high surface pH is reduced through a carbonation reaction[27]. Elastomeric Acrylics are generally not recommended for service over substrates with a surface pH ≥ 11 and, prior to application, the pH of new cementitious surfaces should be tested (mortar joints included)[28]. Brick, however, is made from either clay or shale and generally does not contain sufficient alkali to warrant pH testing. Surface cracks are common to concrete and stucco and, if cracks are ≤ 1/16" width, cracks can be successfully bridged using the Elastomeric Acrylic. To enhance Elastomeric Acrylic adhesion to cementitious materials (excluding weak stucco), either grit blasting or acid etching is highly recommended. If the cementitious material's surface is properly prepared and surface pH < 11, the Elastomeric Acrylic should display high performance on above grade concrete, CMU, stucco, and brick.

Composites and Plastics

Although untested in this investigation, Elastomeric Acrylics applied to properly prepared composites and plastics should develop sound adhesion and enhance UV resistance.

Galvanized Steel

The CTE for zinc is 17.2 x 10^{-6}in/in°F and, when applied to steel (galvanizing), expands at the CTE for steel (5.5 x 10^{-6}in/in°F)[29]. When zinc initially corrodes, zinc salts are generated and display a pH from 5.5 to 9.5[30]. As zinc continues to corrode, zinc salts react with water to form zinc hydroxide at a pH ≥ 9.6[31]. Elastomeric Acrylics, in general, are formulated with zinc oxide at a pH from 9.0 to 9.5 and should remain unaffected when in contact with the corrosion products of zinc[32]. When applied direct to galvanized steel, the Elastomeric Acrylic developed sound adhesion and high performance is anticipated over galvanized surfaces.

Overcoating

In order to prevent an overcoat(s) from lifting an existing coating system, the Residual Cure Stress (RCS) of the overcoat(s) should be significantly less than the adhesive strength of the existing coating system. If, for example, a weathered coating system has a substrate adhesive strength of 250 psi and a two coat overcoat system with a RCS of 350 psi is applied, the overcoat's RCS greatly exceeds the adhesive strength of the existing coating system and significant lifting and/or wrinkling may result. At 38 mils dry, the initial RCS of the Elastomeric Acrylic is 57 psi and, when applied to a sound but weathered coating system, should negligibly contribute to increasing the coating system's stress. Over time, this initial RCS may relax by up to 50 % to further decrease the stress from overcoating[33]. At 12 mils dry, a two-coat Elastomeric Acrylic overcoat may generate an initial RCS of approximately 18 psi. This value is extremely low and, when the Elastomeric Acrylic is used as an overcoat, should prevent the lifting of marginally sound coating systems. Furthermore, the Elastomeric Acrylic applied to the following paints displayed sound adhesion and is an indication of high field performance: A) Acrylic, B) Alkyd, C) Aliphatic urethane, D)

Moisture-cured urethane, E) Epoxy polyamide, and G) Epoxy polyamine. Elastomeric Acrylics, in general, containing a high loading of zinc oxide (alkali source) and may not be suitable for overcoating alkyd/oil-based paints. Alkyd/oil-based paints saponify (turn into a soap-like material when exposed to alkali.

Steel

When a corrosion resistant primer is applied to steel and followed by two topcoats of the Elastomeric Acrylic, a corrosion resistant coating system is produced. However, two to three coats of the Elastomeric Acrylic, applied direct to steel, may not produce an effective corrosion resistant barrier. Since the Elastomeric Acrylic is formulated to breathe, a primer with low permeability, such as an epoxy polyamide primer may be required for use over steel.

Wood

In general, wood has a moisture content of 12 % and, when exposed to external moisture, may swell and increase in volume by up to 11 %[34]. In areas such as board ends where moisture penetrates and induces wood swelling, coatings with insufficient flexibility prematurely lift and peel[35]. The Elastomeric Acrylic developed sound adhesion to plywood and high performance is anticipated on wood substrates.

Limitations

Elastomeric Acrylics are not for use in painting the following surfaces: 1) Wearing surfaces (decks, walkways, floors), 2) Surfaces with ponding water for greater than 24 hours, 3) Surfaces subjected to cycled immersion (splash zone), 4) Buried pipe, 5) Surfaces exposed to elevated temperatures (≥ 170°F), 6) Surfaces subjected to occasional chemical spills, 7) Below grade, and 8) Surfaces requiring waterproofing.

IDEAL ELASTOMERIC ACRYLIC PROPERTIES

Elastomeric Acrylics

Ideal Elastomeric Acrylic properties are listed in Table 7.

Table 7: Ideal Elastomeric Acrylic Properties

PROPERTY	*VALUE OR RESULT*
Water-based Resin System	100 % Waterborne Acrylic Elastomeric
Percent Volume Solids	≥ 50 %
Volatile Organic Compounds (VOCs)	≤ 100 g/l
Lead (ASTM-D-3335)	≤ 0.06 %
Cadmium (ASTM-D-3335)	≤ 0.06 %
Chromium (ASTM-D-3718)	0.00 %

Standard specification for acrylic roof coatings (ASTM-D-6083)	Pass
Early wash-off from rain (fast cure)	*No effect @ 1 hour cure, 70 °F, 80 % R/H*
Early wash-off from rain (standard cure)	*No effect @ 3 hour cure, 70 °F, 70 % R/H*
Color: White (Fed. Std. 595B)	27925 (matte is acceptable)
Color: Red/Orange (Fed. Std. 595)	12197 (semi-gloss or matte is acceptable)
Color: Light Gray (Fed. Std. 595B)	36495, 35622, 36480
White Reflectivity (ASTM-E-1347)	> 90 %
Zinc Oxide (fungicide/extender pigment)	> 4.0 % by weight
Fungi Resistance (ASTM-G-21)	"0" Rating @ 28 days: No visible growth
Application Thickness	3 – 7 mils Dry Film Thickness per coat
Substrate Alkalinity, Continuous Exposure @ pH < 11	No decrease in performance
Acidic Environments, Cyclic Exposure @ pH > 4 (Acidic dew, fog, rain)	No decrease in performance
Humid Environments, Continuous Exposure @ R/H ≤ 85 %	No decrease in performance
Resin Pigment Retention @ 1-year service	0 % visual discoloration from pigment bleed onto adjacent surfaces
Chalking Resistance @ 1-year service (ASTM-D-4214: Method B)	Rating of >> 8
Biological Growth Resistance @ 1-year service (ASTM-D-3247)	Rating of 10 (no visual growth)
Dirt Pickup Resistance @ 1-year service (ASTM-D-3274)	Rating of 10 – or >> 8
Water Absorption @ 73°F, 166 hrs immersion (ASTM-D-471)	≤ 12 % increase in weight
Shore A Hardness @ 73°F (ASTM-D-2240)	65 – 77
Tensile Strength @ 73°F (ASTM-D-412)	≥ 275 psi
Percent Elongation @ 73°F (ASTM-D-412)	200 % - 300 %
Dry Adhesion to Acrylics, DTM Acrylics, Alkyds, Aluminum, Galvanized Steel, Epoxies, Polysulfides, Steel, Urethanes, 73°F, 5 mils dry (ASTM-D-4541)	≥ 275 psi
Dry Adhesion to Brick, Concrete, CMU, Cement Mortars, Wood, 73°F, 5 mils dry (ASTM-D-4541)	≥ 140 psi
Dry Adhesion to Asphaltic substrates, Stucco, 73°F, 5 mils dry (ASTM-D-4541)	100 % cohesive failure in substrate
Wet Adhesion @ 168 hrs immersion in tap water, 73°F, 5 mils dry (ASTM-D-4541)	≥ 90 psi
Dry Adhesion following 168 hrs immersion in tap water, 24 hrs drying, 73°F, 5 mils dry (ASTM-D-4541)	≥ 250 psi
Sag Resistance @ 7 mils Dry Film Thickness, 73°F	No sagging or runs on vertical surfaces
Application/cure temperature range	50°F – 90°F

FINDINGS

- A water-based, Direct to Metal (DTM) acrylic primer followed by 20 mils dry of a water-based, Elastomeric Acrylic has provided excellent protection to steel for over 2.75 years in a coastal marine environment
- Elastomeric Acrylics developed sound adhesion to seventeen combined coated and uncoated substrates
- Elastomeric Acrylics generate low levels of Residual Cure Stress (RCS) and, when used in maintenance painting, should transfer negligible stress to existing coatings
- Elastomeric Acrylics applied direct to steel resulted in significant flash rusting: however, the flash rusting neither affects adhesion nor bleeds into a topcoat when overcoated
- Elastomeric Acrylics exhibit acceptable performance when subjected to one-week immersion in tap water and three-weeks exposure in 95 % Relative Humidity
- Elastomeric Acrylics have displayed high performance when applied to Naval and Commercial roofs
- Elastomeric Acrylics may be suitable for use on a variety of exterior substrates located in diverse environments

RECOMMENDATIONS

1) Initiate laboratory testing for accelerated weathering.
2) Initiate testing at the Naval Research Laboratory (NRL) exposure site in Florida.
3) Identify Naval structures for Elastomeric Acrylic demonstration.
4) Validate Elastomeric Acrylic performance.

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